

THE CURRENT STATUS
OF HONNEF WIND POWER PLANTS

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The most important energy sources on earth, next to the sun /187* and water, are coal and oil. However, it seems from our present knowledge that these deposits will be exhausted in the foreseeable future. Large wind-power plants are destined to play an important role in the tapping of new energy sources. Their viability must be judged from the research and development work carried out in the USSR, the U.K., the U.S.A., and Germany.

ENERGY NEEDS AND ENERGY SOURCES

As developments over the last 50 years have shown, the world is getting hungrier and hungrier for electricity. Present-day experience shows that energy requirements are doubling every 10 years in almost every developed country. World coal reserves amount to about 350 times the present annual power generation and, with increasing usage, will last less than 200 years [1]. But coal and oil deposits not only represent the livelihood of millions of people, but are one of the most important elements of our economic and civilized existence.

The desire to tap suitable energy sources has led to the furtherance of hydraulic projects. The potential of water power, however, is limited. There are tidal power and solar energy plant schemes aplenty, and it is obvious that energy from atomic fission and transformation is of increasing significance. However, the exploitation of usable energy from nuclear reactions is beset with radiation and requires huge capital outlays. For Germany, atomic energy is unthinkable on a long-term basis, for various reasons. In this connection, we may note the observation made

*Numbers in the margin indicate pagination in the foreign text.

at the German Bunsen Society meeting in May, 1954, to the effect that atomic energy on the surface of our planet, radioactive enough as it is, may lead to difficulties.

Wind, which costs nothing, offers a ray of hope in our future energy worries, and the hope is warranted by the development work carried out thus far. Wind exploitation by small plants is quite familiar, but it has long been recognized that small wind energy plants are of little use for supplying large factories or for supplying current to the public power networks - they can only be of local interest. The cost of a small wind plant is high in comparison to the installed power, where the ratio is far more favorable in large wind power plants [2].

However, power output of small and medium-sized wind plants, and the development work invested in them for decades in various countries, have cleared the way for the realization of large wind energy plants, which require only a fraction of the outlays for nuclear power stations [3].

The idea of building large wind-power plants was publicly aired for the first time in the twenties in Germany, and discussions on this type of energy production have not subsided since that time. The difficulties confronting it are comparable with the difficulties that had to be overcome in the exploitation of water power in its early days.

STATUS OF DEVELOPMENT WORK

We already mentioned in our introduction that work is being done the world over to develop large wind power plants. Little is known, unfortunately, about the USSR's tests on a 100 kW plant in Balaclava, Crimea, with its 30 m diameter wind wheel [4], operated in parallel with the public network. This plant ran for nearly 10 years, beginning in 1931, and was destroyed during the war. Moscow's Central Wind Institute has carefully studied the knowledge gained from it, and

the 100 kW plant is regarded as a step towards developing a 5 mW wind generator, which by now should have been built. Data is not obtainable, however [5], but one may assume from this project that the results from the 100 kW plant must have been satisfactory.

In the USA P.C. Putnam caught hold of the idea of large wind-power plants, and built a 1 mW plant on Grandpa's Knob, Vermont. With its gears, hydraulic control, and two 53.1 m diameter turning blades atop a 32.5 m tower, it has provided valuable knowledge (Figure 1). However, the installed power could not be turned to full account as the blades were not high enough above the ground. In evaluating its results we must remember that the plant was working under unfavorable conditions in the most turbulent region of the ground eddy zone, with corresponding loads.



Figure 1. Putnam's 1 mW plant on Grandpa's Knob.

The wind wheel started to turn at a wind speed of 2-3 m/s. At high rotation speeds the propeller tips reached relative velocities above the speed of sound, causing substantial efficiency losses because the engine was racing. The plant had to be monitored and serviced continuously as it was liable to damage at so many spots. For instance, the gears and propeller were unbalanced in the ground eddy zone because the center of pressure was higher than the center of rotation. This could have

been avoided by building a higher tower to take advantage of better wind conditions. Finally, one blade broke at its root through

overloading. Earlier German propeller experiments sustained similar damage, for instance the small Heuberg plant in the Berlin Zoo.

Practice has shown over and over again that blade loading caused by bending and centrifugal force in the resonant range of the oscillations can lead to breakage. The USA plant once more demonstrated that, in view of the deficiencies described and the insufficient height, the additional costs required to build a higher tower pay off in terms of safety and continuously improved efficiency in the higher zone.

Recently, the U.K. has been seriously tackling the problem /188 of large wind-power plants. The British Electricity Authority has tested two 100 kW plants of different designs, and is planning to build 50 to 60 wind-power plants producing 1 mW each on towers about 80 meters high in various regions of the British Isles [7].

One of these 100 kW plants was built according to the design of Andreau, a Frenchman, on the Lleyen peninsula, to supply the public network. It has a two-bladed propeller of 24.4 m diameter on a 30 m steel tower, guyed 16 m up; its lower part hollow, made of steel, and 4 m diameter. Figure 2 shows the wind-power plant while under construction¹. When the blades rotate, the air inside them is forced outside through openings in the blade tips. This produces a pressure drop inside the blades. Air is sucked out of the hollow tower through the hollow hub and the air stream drives a turbine in the lower part of the tower, which is mounted on a generator shaft². Figure 2 clearly shows the air intake apertures in the thick lower part of the hollow mast and the outlet apertures in the blade tips. The tapered tower head bears a

¹The picture was kindly made available by the periodical "Orion" (Orion, Vol. 9, p. 894, 1954).

²See ETZ-B, Vol. 7, No. 5, p. 194, 1955.

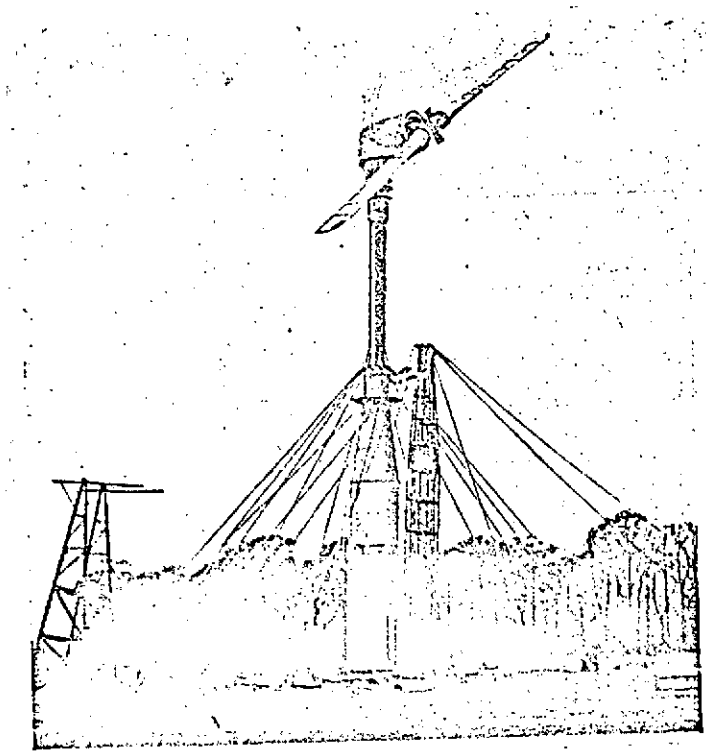


Figure 2. 100 kW wind-power plant, 30 m high, in England, from J. Andreau's design.

2 m diameter tube on which the propeller turns.

The position of the blades with respect to the wind is adjusted such that the peak power of 100 kW is reached with wind velocities of 13.4 m/s. If the wind blows at more than 29.1 m/s - up to which the power output is constant - the turbine is shut off to prevent damage.

The turbine is designed to start at a wind speed of 7.6 m/s and reach its maximum rpm (95) at a wind speed of 13.4 m/s, when the propeller is rotating at 1000 rpm.

Its efficiency is low,

and it is feared that the centrifugal force acting on the swivel joint will act together with the torque, so that oscillations strain the blade at its point of attachment to breaking point. The question of stability and economic viability can only be resolved after a certain trial period.

With this project, The U.K. opposes the all-too-frequently-held view that experience must be gathered on small plants. Plenty of these are available, and have nothing to add to evaluation of large plants. In the opinion of A. Kroms (USA) [7], and of H. Witte (Germany) [8], larger research plants with high installed powers and large-diameter wind wheels must be built at

sufficient heights and connected in parallel operation with the public network.

HONNEF'S WIND TURBINES

These advances are along the same lines as the years of efforts in Germany, where H. Honnef disseminated the concept of the large wind-power plant many years ago. It is a widely-held view that his work encompassed the design of large plants only. However, for several decades Honnef's research and development work also included wind-power plants of 0.5 to 1000 kW. These plants are characterized by gear-less, counterrotating, tiltable ring turbines with fixed blades. The current-generating components are inside the rings [9-11].

In 1923 Honnef was the first [12] to develop and carry forward the idea of wind exploitation on a large scale. He was led to this idea by his years of experience as a statics engineer, building of high towers (up to 274 meters) and other structures. A particularity of Honnef's design is the roller bearing for the tiltable wind turbine [13-15] whereby the turbine is tilted in stages, overloading is avoided, and the output is regulated mechanically (Figures 3 and 4). This design has stood the test of practice.

Tilting the wind turbine keeps its output constant from 15 m/s wind speed downwards, preventing continuous overloading [23]. The moments of inertia of the tilting on the roller bearing are equalized with the torques caused by wind forces. The motion is controlled by electric impulses through a voltage generator (marked 5 in Figure 4) ahead of the turbine, that is adjusted such that output and axial thrust remain constant. Above 12 m/s the turbine is tilted at an angle of 30° , and above 15 m/s the real regulation giving a constant output, in 6th steps, comes into play, one to two seconds being required for each step. The steps have the ratio of 1:2 between them and can be regulated to the rpm or voltage without difficulty.

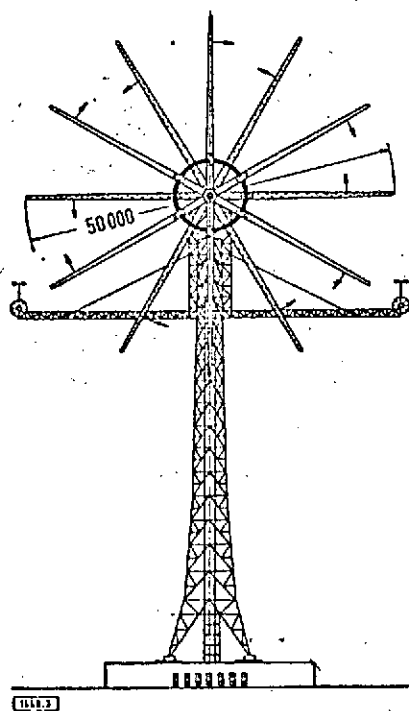


Figure 3. Counterrotating 1 mW power plant with exciter turbines for a hill 290, Rottland.

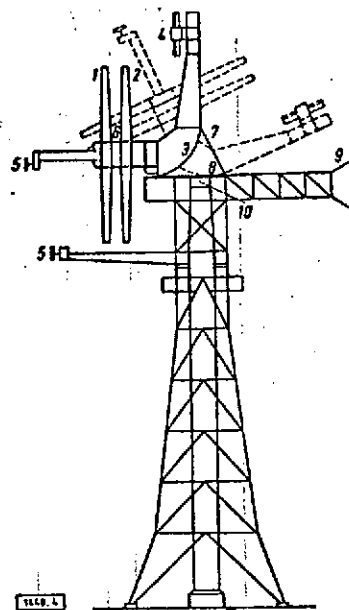


Figure 4. Basic concept of the tiltable wind turbine. 1. Pole wheel; 2. armature wheel; 3. roller bearing of fixed axis; 4. exciter turbine; 5. wind antenna and voltage generator; 6. current generator; 7. electrically-controlled tilting drive; 8. turntable; 9. tail; 10. main rotary bearing. In dashed lines; turbine in the tilted position.

With wind gusts, rising from 15 to 25 m/s in the very short time of 2 seconds, a tilting angle of about 55° would be necessary. When the wind is blowing at 15 m/s however, the turbine is already

tilted at 30° , so that it only has to turn through a further 25° , which requires four to eight seconds. The maximum temporary load on the generator caused by the equalizing processes amounts after three seconds to only about one and a half times the rated moment, because the turbine has tilted through 10° after three seconds and is then tilted at about 40° . The assembly then runs again for a further five seconds with the rated load. It is thus possible to make optimum use of the entire range of wind forces.

With regard to design, the arrangement of the generator components is the same when three-phase and direct current are being generated. In each case the pole wheel and the armature, are built as concentric rings which support the wind blades (Figure 5).

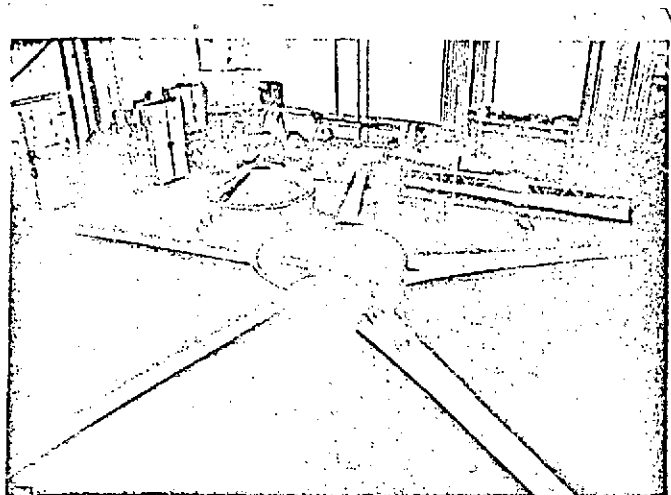


Figure 5. Lower part of the counter-rotating turbine in the workshop at Mathias Hill testing ground.

The blades are angled such that the two rings turn in opposite directions. The field spider and armature rings are held by special bearing rings which prevent elastic strain from becoming too great.

An economic usage of iron for the electric ring installations was achieved by C. Martini [18] when the armature bore is one-fifth to one-third of the turbine diameter. For a turbine output of 15 mW the diameter between blade tips is 156 meters, of which the

generator rings account for 30-40 meters.

In a comprehensive report, H. Witte (1936, [16]) comes to the conclusion that it would be advantageous to erect a larger Honnef-type research plant, and mentions that he has available very de-

tailed data, calculations, and expert opinions for evaluation. In a later article Witte deals with the economics and feasibility of large wind-power plants [8].

After preliminary calculations and wind readings on radio towers, tests were conducted in the wind tunnel of the Aerodynamic Research Institute at Gottingen, and the Aeronautical Research Institute in Berlin-Adlershof, which show good results for efficiency and output. The energy balance of the technical research report on electricity by E. Merkel and the electronics report by R. Richter on the Adlershof tests, argue for a large facility [16]. Unfortunately, the building planned for 1938/39 with a four-million reichmark government credit had to be postponed due to urgent armaments work. Nonetheless, Kloss, Föttinger, Hertwig, Robitzsch, Witte, and Steinmann reported in late 1939, on the basis of the Adlershof tests, that "this is an extraordinarily worthwhile project which not only shows the Honnef design to be valuable under specific technical feasibility conditions, but moreover has shown that Honnef, in his decades of preliminary work, had provided the basis for solving the wind power question in general, which must be sustained and extended at all costs".

RESEARCH PLANTS

Beginning in 1940, Honnef built a large-scale testing ground on Mathias Hill in Botzow-Velben near Berlin (60 m high). Under the leadership of J. Koniger, thirteen different designs were tested up to 1945, mainly plants with a tilting generator and fixed blades, but also plants with adjustable blade angles (Figures 6 and 7), sensitive measuring instruments, gust recorders, combined and multi-channel recorders. Their results were evaluated. The wind-power plants were tested over a long period in /190 wind and weather. The counterrotating turbine ran without friction in these research plants, and sustained no damage or breakage.

The easy startup of the tilting turbine with a wind of 0-1 m/s caused particular astonishment. Another surprise was the electric

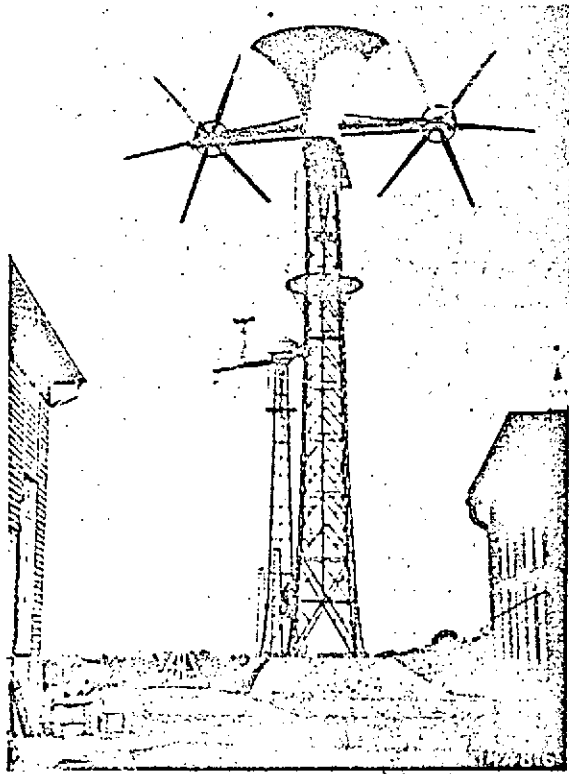


Figure 6. Twin power station; single d.c. plant, switching building and weather station at Honnef's Mathias Hill testing ground.

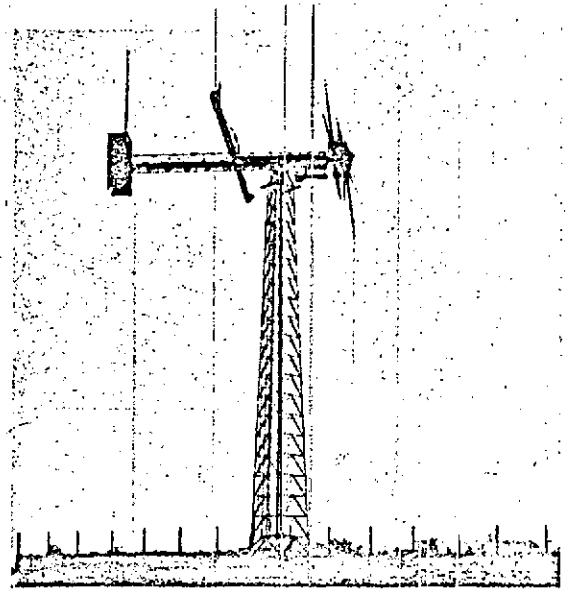


Figure 7. Counterrotating three-phase power plant (AEG) at the Mathias Hill testing ground.

power output, which at 3-3.5 m/s already exceeded the machine's own consumption. This was the first time that electric power had been generated at such low wind velocities [17].

Two of the plants at the Mathias Hill testing ground will be briefly dealt with, since the experience gained served as a basis for the 1 mW plant built by AEG [16].

A three-phase generating plant of 10 kVA with a wind of 4-5 m/s was installed by AEG as a counterrotating tilting turbine. Ten meters in diameter and mounted on a 30 m tower, this plant

produced 20 kW at 10 m/s, and over 30 kW with increasing wind velocity. Figure 8 shows the generator.

A d.c. generating plant was started up in 1940 on the basis of electrical information from L. Linner and an aerodynamic design by E. Merkel. This plant had a maximum output when tilted of 15 m/s and delivered 60 kW.

These plants provided power and energy for lighting, ventilation, and heating of the buildings at the testing ground. Moreover, two hundred 40-60 W incandescent lamps were installed in the switching building, supplied directly by the plant, and burning steadily without a battery [16]. Investigations of the generating plant with an Askania monitoring oscillograph and the Geiger vibrograph by W. Zeller showed no natural oscillation of the tower and its structural components in resonance with the oscillating turbine.

The plants worked perfectly over nearly five years, even in the hard winter of 1941-42, and withstood a trial which was only put to an end by the war.

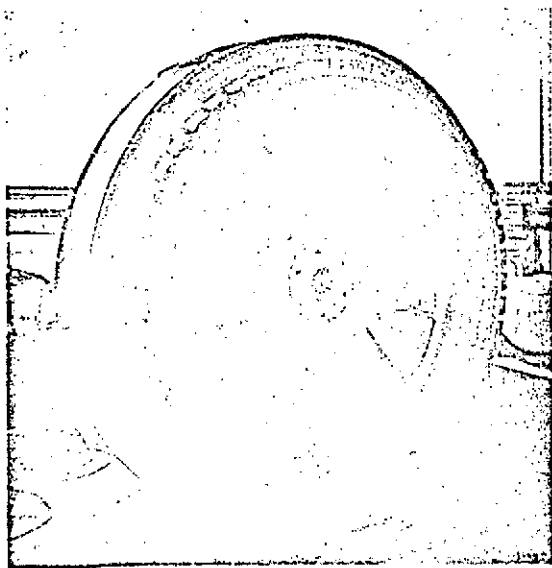


Figure 8. Exciter machine of Honnef's wind-power plant, in the workshop at the Mathias Hill testing ground.

In 1944 the AEG built a counterrotating Honnef three-phase synchronous sweep generator with 1 MW rated output, about 50 m diameter between the blade tips, 10 m armature bore, and a 6 mm air gap (Figure 3). The fixed blades with aluminum skins and ribs were 170 cm wide at the root and measured 15 m in maximum length. The generator rotated at 28.5 rpm, and there were 210 poles. The armature and damping windings were made from aluminum, and the pole windings from copper with a

laminated core and solid pole shoes.

This plant never was delivered to the testing ground, but in 1944 it was delivered to Hill 290 in Rottland, near Waldbrohl (Rhineland), where wind readings had been taken for a long time. Mounted on an 80 m free-standing steel tower, this plant was to work in parallel with the RWE overhead transmission network, and negotiations for this purpose were conducted in 1943 between the RWE and EW-Siegerland GmbH, and the AEG and Honnef.

The tower installation work on Hill 290 was underway, the most important buildings with control, measuring, and high-voltage installations were in place, when further construction had to be suspended and the generator dismounted and removed, due to air-raids of increasing intensity. This precaution did not save it from loss, as the testing ground in Bötzwow was also totally destroyed by the battles around Berlin in 1945.

An existing report [18] describes the design of the large wind-power generators.

ECONOMICS AND YEARLY OUTPUT

As stated in the introduction, the world's economy is demanding more and more energy. The consumption of aluminum, for instance, has like energy needs, doubled every ten years. Aluminum production is largely a matter of energy. To make one ton of aluminum requires about 20,000 kWh, accounting for about 40% of the production costs in Germany, for example. In view of the energy circumstances already mentioned, large wind-power plants could also be of importance in this sphere too.

According to the Honnef design [19], steel tower about 240m high would require counter-rotating tilting turbines of about 156 m diameter with a rated output of 15 mW. Such a plant would generate 40 million kWh in one year. This figure was established by calculations; other sources [8, 20] give a figure of as much as 60 million kWh per year. The output calculated by Honnef [9, 21] in fact is exceeded sometimes on the basis of altitude wind measurements. For the Brocken, for example, a yearly output of 81

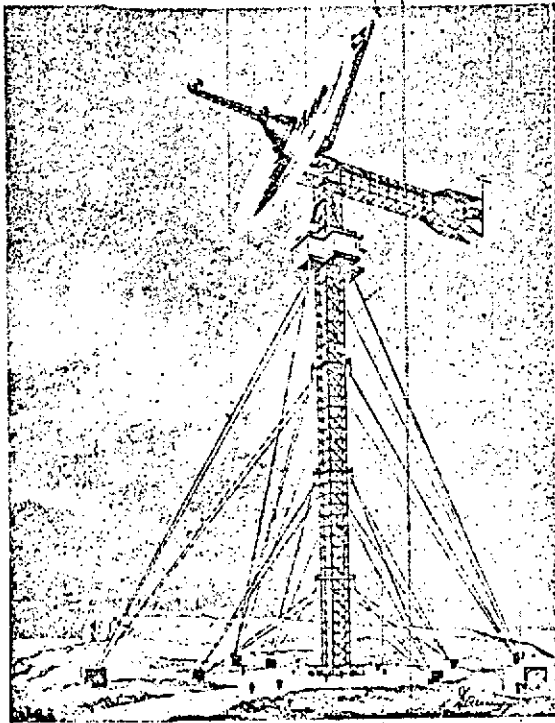


Figure 9. Artist's concept of a large Honnef wind-power plant, by W. Damm.

million kWh when working independently and 79.6 million kWh when feeding into the network were calculated. According to the characteristic power curve as established by Kloss [22] and further developed by Linner [23] the economy of large wind-power plants can be shown on the basis of yearly output.

Altitude wind measurements from various meteorological stations in Germany give an idea of the frequency with which wind velocities occur. Drawing on this information, Table 1 shows the yearly output of a 15 mW wind generator at various wind measurement points in Germany.

Heat and friction losses have been taken into account. It can be seen that the yearly output with operation on the public network is only slightly less than with independent operation. Part of the difference becomes available if the generator is switched to an energy storing device, for instance when the wind velocity rises above 6.5 m/s.

Table 1. Yearly output in millions of kWh of the counter-rotating 15 mW generator, with wheel diameter 156m /191

| Wind measuring point | Hohen- peis- senberg | Wil- helms- haven | Berlin | Zug- spitze | List auf Sylt | Kahlen Astern | Brocken Harz |
|----------------------------|----------------------------|-------------------------|--------|----------------|---------------------|------------------|-----------------|
| Network operation | 26.4 | 38.2 | 39.0 | 41.2 | 61.4 | 67.0 | 79.6 |
| Individual operation | 29.8 | 42.2 | 42.4 | 44.6 | 63.7 | 70.5 | 81.0 |

With network operation we may expect an improvement in the network output factor, and, correspondingly, use of presently unused power from the generators working in parallel. Parallel operation of the wind-power plant is economic under certain conditions even with lower wind velocities--as the case may be, from below 6.64 m/s to below 4 m/s, when the synchronous machine delivers a correspondingly large amount of hitherto unused power into the network lines, working as an over-excited motor with a slight increase in actual efficiency when the wind is less than 6.64 m/s. In this case the operating times with network operation will be almost as long as with independent operation.

The counter-rotating and thus two-wheel turbines developed by Honnef can also generate high-power direct current directly.. The power is divided into controllable stages, and can be delivered to the consumer in the form of direct current, or, after being transformed, as three-phase current. According to the rpm and voltage controllability, the d. c. wind generators can operate in parallel with a three phase network without extra accessories.

The tilting turbine with mechanical power regulation can also be used in independent operation over the whole range of the most frequently occurring wind velocities, 3-15 m/s. This range is larger than with parallel operation of the three-phase current wind-power generators, since the d.c. generator can also use the comparatively frequent wind with velocities of 3-7 m/s.

Large wind-power plants offer the advantage that synchronous three-phase network operation is simple and that they adjust in stages to the available power. Their yearly output is very high, the installation cost is modest, and the economics of the gearless tilting generator are good. Large wind-power plants can either supply current individually, together with an energy storing device, or be used in combination. In parallel operation with the three-phase network the large wind-power plant is not directly influenced by line frequency. Only the three-phase side of the converter stage is frequency-dependent. For this reason, the

flywheel masses of the wind turbines can accept short strong gusts without difficulty. The rpm and voltage fluctuations from short squalls are limited and equalization between stages is made easier.

SUMMARY

One of the ways of meeting the world's increasing energy demands is the building of large wind-power plants. Tests have shown that wind-power plants designed to feed into the public network must have a high power output. However, high outputs can be provided only by large-diameter wind wheels working at economic and uniform high altitudes with strong winds.

Honnef's decades of preliminary work have shown that no technical problems stand in the way of renewed construction of such plants.

Only large scale tests can show convincingly whether it is justifiable to connect large wind-power plants into a large-scale power supply network, and relieve part of the burden of finding new energy sources.

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